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Sustainable Mining via Waste Valorisation: Electrokinetic In Situ Recovery of Critical Metals from Mine Tailings

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The urgent shift towards a low-carbon economy is causing an unprecedented demand for critical metals such as Cu, Co and Ni, that will need to be satisfied by increased mining activities. Unfortunately, declining ore grades and the increasing depths of newly discovered ore bodies cause rising strip ratios and associated increasing environmental impacts. This has led to the re-evaluation of exploiting the vast amounts of critical metals that typically reside in mine tailings, often at grades exceeding that of newly mined ore. Furthermore, older legacy mine tailings may also contain appreciable amounts of elements that were of little or no interest during initial ore processing, such as rare earth elements (REEs), that are now in high demand. To date, all proposed technologies for metal recovery from mine tailings involve the costly excavation and haulage of the tailings material prior to its ex situ reprocessing and redeposition. Here, we investigate the viability of an alternative approach, electrokinetic in situ recovery (EK-ISR), which could simplify recovery and operate as a completely electrified process. EK-ISR relies on the application of electric fields via electrodes of opposite polarity to (i) induce the transport of ore-specific lixiviants across the tailings material and (ii) the transport of solubilized metals towards a recovery point. Overcoming the low hydraulic permeability of the tailings materials, solute transport between electrodes is largely governed by both, electromigration and electro-osmosis.

In this work we present a series of systematic laboratory-scale leaching experiments using (i) synthetic tailings material containing well-defined quantities of metals and of simplified mineralogical composition and (ii) real tailings material. We illustrate the temporal recoveries of different metals including Cu and Co and unravel the complex interplay of physical transport and geochemical reaction processes that control the metal recovery efficiency during EK-ISR for the selected sample materials.